Cycloaddition as a Possible Path to Disaccharide Synthesis: Stereochemical Course of the Reaction of Butyl Glyoxylate with a Chiral, Protected Dienyl Ether of Glucose [1]

By **Serge David,* Jacques Eustache,** and **André Lubineau,** Laboratoire de Chimie Organique Multifonctionnelle, Université de Paris-Sud, 91405 Orsay, France

The addition of 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (2) to 2,7-dimethylocta-3,6-diyne-2,7-diol (1) gave a mixture of *cis*- (3) and *trans*- (4) 3-but-1-en-3-ynyl ethers, which were separated and partially hydrogenated to give the corresponding dienyl ethers (5) and (6). These were also obtained by a Wittig reaction of the phosphorane derived from 1,2:5,6-di-*O*-isopropylidene-3-*O*-(triphenylphosphoniomethyl)-α-D-glucofuranose chloride (9) with acrylaldehyde. The reaction of butyl glyoxylate with the *trans*-diene gave principally the trideoxydisaccharide of *cis*-configuration (11).

OLIGOSACCHARIDES are usually synthesised by consecutive reactions of activated and partially protected monosaccharide units, but this general method, which is also that of their biosynthesis, is not always very satisfactory. We report here a preliminary study of a different approach, prompted by a report of the cycloaddition of butyl glyoxylate to 1-methoxybuta-1,3-diene,[2] which led to the preparation of four racemic methyl hexopyranosides.[3] Other workers have followed similar approaches.[4] These methods allow in principle the synthesis of a disaccharide to be visualised in three main steps: (i) synthesis of a dienyl ether of a monosaccharide, (ii) cycloaddition, and (iii) introduction of functional groups into the non-reducing unit of the polydeoxy- ' disaccharide ' thus obtained.

The ready base-catalysed addition of an alcohol to 2,7-dimethylocta-3,5-diyne-2,7-diol (1) has been demonstrated,[5] and we have found that the addition of 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose (2) to compound (1) (2 equiv.) at 80° in tetrahydrofuran in the presence of potassium hydroxide (0·1 equiv.) gives almost quantitatively a mixture of the two enynyl ethers (3) and (4). These were separable by column chromatography on silica gel and could be distinguished by their ^{1}H n.m.r. spectra, the crystalline *cis*-derivative (3) having $^3J_{1',2'}$ 6·0 Hz and the liquid *trans*-derivative (4) $^3J_{1',2}$ 13·0 Hz. Each of these enynyl ethers could be partially hydrogenated in the presence of quinoline and palladium–barium sulphate to give the corresponding dienyl ether [(5) and (6), respectively] as a distillable liquid. However, since the *cis*-diene (5) is inert in the following

[1] Preliminary publication, S. David, J. Eustache, and A. Lubineau, *Compt. rend.*, 1973, **276**, 146.

[2] A. Konowal, J. Jurczak, and A. Zamojski, *Roczniki Chem.*, 1968, **42**, 2045.

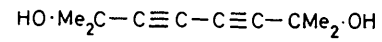
[3] A. Banaszek, *Bull. Acad. polon. Sci., Sér. Sci. chim.*, 1972, **20**, 925.

[4] U. P. Singh and R. K. Brown, *Canad. J. Chem.*, 1971, **49**, 3342.

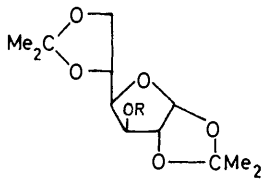
[5] V. F. Kucherov, *Izvest. Akad. Nauk S.S.S.R., Ser. khim.*, 1964, **7**, 1318.

cycloaddition step, the chromatographic separation of the enynyl ether precursors is not absolutely necessary.

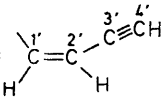
We have also prepared the dienyl ethers (5) and (6) by a Wittig reaction; the advantage of this reaction is its wide applicability, which could facilitate the introduction of substituents into the diene. Treatment of

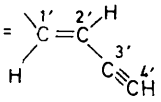


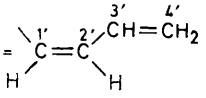
(1)

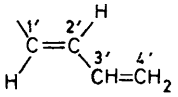


(2) R = H

(3) R = 

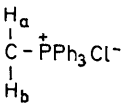
(4) R = 

(5) R = 

(6) R = 

(7) R = CH_2SMe

(8) R = CH_2Cl

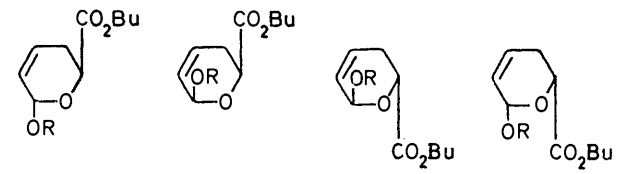
(9) R = 

the sodium salt of (2) with chloromethyl methyl thioether gave the (methylthio)methyl ether (7), previously described [6] as a by-product in the oxidation of (2) with dimethyl sulphoxide. Compound (7) was converted into the chloromethyl ether (8) in 91% yield by treatment with chlorine in tetrachloromethane. The quaternisation of triphenylphosphine by the chloromethyl ether (8) was quantitative and the phosphonium salt (9) could be isolated as a hygroscopic crystalline solid. The phosphorane prepared by addition of phenyl-lithium to an ethereal solutions of the salt (9) reacted rapidly with acrolylaldehyde *in situ* to give a mixture of the ethers (5) and (6), which could be used directly in the next step.

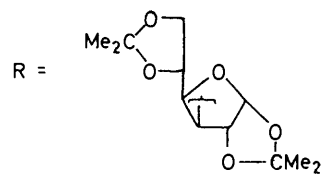
Compounds (3)—(6), (8), and (9) are relatively simple and highly reactive ethers of sugars of which, to the best of our knowledge, no analogues have been prepared hitherto. Our new method for the preparation of dienyl ethers based on the Wittig reaction can obviously be applied in areas other than carbohydrate chemistry.

The cycloaddition of butyl glyoxylate to the *trans*-dienyl ether (6) was complete after 14 days at 20° [while there was no apparent reaction with the *cis*-ether (5)]. Four components, A—D in order of increasing polarity, were detected in the reaction mixture by t.l.c. on silica gel. They showed virtually identical i.r. spectra and obviously corresponded to the four predicted diastereoisomers (10)—(13). A mixture of A and B separated from the other components by column chromatography was obtained as a distillable oil having the expected analytical and spectral properties. Reduction of the ester function with lithium aluminium hydride then gave a distillable mixture of the alcohols having the expected composition.

The isomerisation demonstrated with simple model compounds [7] allowed a simplification of the reaction mixture as follows: isomerisation of the A–B mixture or of the C–D mixture under acidic conditions led to an A–D mixture; components A and D are therefore those with the *trans*-configuration, (10) and (12). Components A and D were then separable by column chromatography on silica gel. The final assignments of configuration (10) to A and (12) to D rests on their degradation into the 2,3,4-trideoxyhexopyranose enantiomers (17) and (18). For this reason we shall first discuss the synthesis of the reference compound (17). A Wittig condensation between the phosphorane derived from 3-chloro-1,1-diethoxypropane and 2,3-*O*-isopropylidene-D-glyceraldehyde gave a moderate yield of the ethylenic acetal (14) (possibly a *cis–trans*-mixture). The acetal (15) was obtained by catalytic hydrogenation, and mild acidic hydrolysis with 80% acetic acid led to an oil having the elemental composition of an ethyl glycoside (16). Treatment of this, or of the acetal (15), with 0·5M-sulphuric acid gave 2,3,4-trideoxy-D-hexopyranose (17), $[\alpha]_D^{25}$ +46·9° (*c* 4·7 in CH_2Cl_2). This series of reactions was conducted in such a way as to allow the isolation of extremely pure compounds without regard to yield. The absence of carbonyl absorption in the i.r. spectrum of compound (17) in dichloromethane solution proved its hemiacetal



α-D (10) (=A) β-D (11) (=C) α-L (12) (=D) β-L (13) (=B)

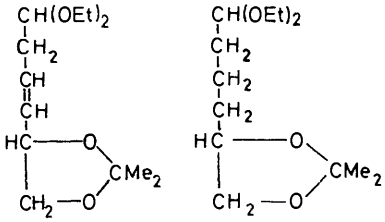
R = 

structure; the measured optical rotation was possibly that of an anomeric mixture.

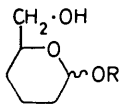
Compound A was reduced to the unsaturated primary alcohol (A′) by lithium aluminium hydride and the double bond of A′ was hydrogenated in the presence of Adams catalyst. A crystalline polydeoxy-'disaccharide' (A″) was thus obtained which was hydro-

[6] J. S. Jewell and W. A. Szarek, *Tetrahedron Letters*, 1969, **43**.
[7] A. Zamojski, A. Konowal, and J. Jurczak, *Roczniki Chem.*, 1970, **44**, 1981.

lysed with 0·5M-sulphuric acid. The difficult separation of the polydeoxyhexose from glucose allowed isolation of the former in only 26% yield, as a syrup, $[\alpha]_D^{25}$ +45·9° (*c* 1·4 in CH_2Cl_2), homogeneous on t.l.c. The



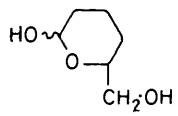
(14) (15)



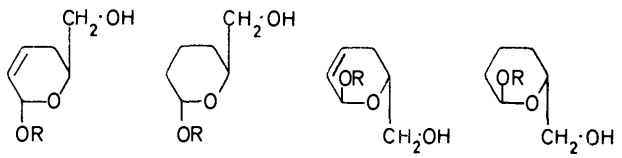
(16) R = Et
(17) R = H

configuration is therefore D at C-5 and the structures (20), (19), and (10) are deduced for A″, A′, and A, respectively.

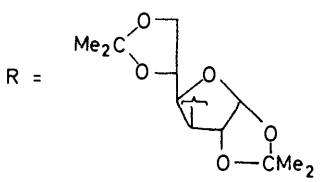
This has been confirmed by a similar conversion of compound D. In this case it was the alcohol D′ resulting from the lithium aluminium hydride reduction



(18)



(19) (20) (21) (22)



of D which was crystalline. Catalytic hydrogenation of D′ gave the polydeoxy-'disaccharide' D″, from which a syrupy 2,3,4-trideoxyhexose (18) was obtained by acidic hydrolysis. The optical rotation ($[\alpha]_D^{25}$) of (18) under the same conditions as above was −44·2°. From this are deduced the L-configuration for (18) and the structures (22), (21), and (12) for D″, D′, and D, respectively.

[8] J. D. Morrison and H. S. Mosher, 'Asymmetric Organic Reactions,' Prentice-Hall, New Jersey, 1971, p. 252.

The components A and B must be epimeric at C-5 because they are converted exclusively one into the other by sodium butoxide in butanol. This determines the configuration (13) for compound B. A similar alkaline isomerisation confirms that C and D are epimeric at C-5 and consequently C has the configuration (11).

The cycloaddition reaction also constitutes an asymmetric synthesis of substituted di- and tetra-hydropyrans, and is interesting in a more general context since there is a lack of information on the course of a cycloaddition to a chiral diene.[8]

EXPERIMENTAL

General Methods.—These were as described in ref. 9.

3-O-(*But*-1-*en*-3-*ynyl*)-1,2:5,6-*di*-O-*isopropylidene*-α-D-*glucofuranose* [(3) *and* (4)].—A solution of the diacetylenic glycol (1) (4·98 g, 30 mmol) in tetrahydrofuran (40 ml) was added dropwise to a solution of the acetal (2) (3·9 g, 15 mmol) and potassium hydroxide (0·1 g) in tetrahydrofuran (30 ml) maintained at 80° under nitrogen. After 16 h at 80° the mixture was cooled and filtered, and the filtrate concentrated to dryness. An aqueous solution of the residue was extracted with chloroform and the organic extract was washed (H_2O), dried, and applied to a column of silica gel (180 g). Elution with benzene–ethyl acetate (7 : 1), gave the mixed enynyl ethers (3) and (4) (4·46 g, 96%).

A mixture of (3) and (4) was rechromatographed on a column of silica gel (100 × 5 cm) with ether–petroleum (1 : 3) as eluant (20 ml fractions). Fractions 100—140 gave the trans-*enynyl ether* (4) as an oil (3·2 g), $\nu_{max.}$ (film) 2100 (C≡C) and 3270 cm^{-1} (CH≡), δ ($CDCl_3$) 2·80 (1H, d, $J_{2',4'}$ 2 Hz, 4′-H), 5·02 (1H, q, $J_{1',2'}$ 13 Hz, 2′-H), and 6·85 (1H, d, 1′-H) (Found: C, 61·8; H, 7·4; O, 31·0. $C_{16}H_{22}O_6$ requires C, 61·9; H, 7·15; O, 30·9%). Fractions 150—200 gave the cis-*enynyl ether* (3) (3·8 g) as a crystalline solid, m.p. 83—85° (from petroleum), $\nu_{max.}$ (film) 2100 (C≡C) and 3270 cm^{-1} (CH≡), δ ($CDCl_3$) 3·02 (1H, d, $J_{2',4'}$ 2·0 Hz, 4′-H), 4·55 (1H, q, $J_{1',2'}$ 6·0 Hz, 2′-H), and 6·45 (1H, d, 1′-H) (Found: C, 61·85; H, 7·2; O, 30·95%).

3-O-(*Buta*-1,3-*dienyl*)-1,2:5,6-*di*-O-*isopropylidene*-α-D-*glucofuranose* [(5) *and* (6)].—A solution of (3) (2 g) in petroleum (50 ml) was hydrogenated over palladium–barium sulphate (5%; 0·15 g) in the presence of quinoline (0·15 g) for 30 min. The mixture was filtered through Celite and concentrated to an *oil* (5) (100%), b.p. 115° at 0·01 mmHg, $\nu_{max.}$ (film) 1600 and 1650 cm^{-1} (diene), δ ($CDCl_3$) 4·8—5·3 (3H, m, 2′-H, 4′-H_2), 6·05 (1H, q, $J_{1',2'}$ 6, $J_{1',3'}$ 0·7 Hz, 1′-H), and 6·62 [1H, 12-line m, $J_{2',3'}$ 10, $J_{3',4'}$(*trans*) 17·3, $J_{3',4'}$(*cis*) 10·3 Hz, 3′-H] (Found: C, 61·4; H, 7·7; O, 30·55. $C_{16}H_{24}O_6$ requires C, 61·5; H, 7·75; O, 30·3%).

A similar reduction of (4) gave (6) as an *oil* (100%), b.p. 115° at 0·01 mmHg, $\nu_{max.}$ (film) 1600 and 1650 cm^{-1} (diene), δ ($CDCl_3$) 4·75—5·2 (2H, m, 4′-H_2), 5·67 (1H, q, $J_{1',2'}$ 12, $J_{2,3'}$ 10 Hz, 2′-H), 6·24 [1H, sext, $J_{3',4'}$(*trans*) 17, $J_{3',4'}$(*cis*) 10 Hz, 3′-H], and 6·54 (1H, d, 1′-H) (Found: C, 61·6; H, 7·7; O, 30·7%).

1,2:5,6-*Di*-O-*isopropylidene*-3-O-(*methylthio*)*methyl*-α-D-*glucofuranose* (7).—A 55% suspension of sodium hydride

[9] S. David, C. A. Johnson, and A. Veyrieres, *Carbohydrate Res.*, 1973, **28**, 121.

in oil (4·8 g) was added in portions to a solution of (2) (26 g) in tetrahydrofuran (200 ml) stirred at room temperature; evolution of gas was allowed to subside after each addition. After a further 2 h the evolution of gas had ceased and a clear solution remained. Hexamethylphosphoric triamide (4 ml), sodium iodide (30 g), and chloromethyl methyl thioether (9 ml; 5% excess) were then added successively. After 3 h the solvent was evaporated off and the residue was partitioned between water and benzene. The organic solution was washed with water and then three times with ice-cold 3N-sulphuric acid. The excess of iodomethyl methyl thioether was extracted by washing with aqueous sodium hydrogen carbonate and the organic phase was then washed several times with water, dried, and concentrated to a red syrup, which was applied to a column of silica gel (400 g). Elution with benzene–ethyl acetate (5 : 1) gave initially compound (7) (16·5 g, 45%), n.m.r. spectrum identical with that reported.[6]

Further elution gave 3,3′-bis-(1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranosyl)methane (1 g), δ ($CDCl_3$) 1·38, 1·39, 1·45, and 1·52 (24-H, 4 s, 4 CMe_2), 4·0—4·4 (10H), 4·60 (2H, d, $J_{1,2} = J_{1'2'} = 5$ Hz, 2-H, 2′-H), 4·90 (2H, $O{\cdot}CH_2{\cdot}O$), and 5·93 (2H, d, 1-H, 1′-H).

3-O-*Chloromethyl*-1,2:5,6-*di*-O-*isopropylidene*-α-D-*glucofuranose* (8).—Compound (7) (4·8 g, 15 mmol) was dissolved in a 1M-solution of chlorine in tetrachloromethane (18 ml). The mixture became slightly warm and the vessel was stoppered and set aside for 30 min. Volatile components were then evaporated off at 50° and 0·1 mmHg, and t.l.c. (benzene–ethyl acetate, 6 : 1) indicated the absence of starting material in the pale yellow syrup and the presence of a single product which decomposed on the plates. The syrup was distilled under reduced pressure to give *compound* (8) (4·2 g, 91%), b.p. 103—105° at 0·02 mmHg, δ ($CDCl_3$) 1·43 (6H, s, CMe_2), 1·52 (3H, s, CMe), 1·59 (3H, s, CMe), 4·0—4·22 (4H, 4-H, 5-H, 6-H_2), 4·39 (1H, s, 3-H), 4·66 (1H, d, $J_{1,2}$ 3 Hz, 2-H), 5·56 (2H, d, J_{gem} 1 Hz, $O{\cdot}CH_2Cl$), and 5·84 (1H, d, 1-H) (Found: C, 51·3; H, 7·05; Cl, 11·3; O, 30·6. $C_{18}H_{21}ClO_6$ requires C, 50·6; H, 6·85; Cl, 11·5; O, 31·1%).

1,2:5,6-*Di*-O-*isopropylidene*-3-O-(*triphenylphosphoniomethyl*)-α-D-*glucofuranose Chloride* (9).—The crude, non-distilled chloromethyl ether (8), prepared from the (methylthio)methyl ether (7) (1·6 g, 5 mmol) as described above, was added to triphenylphosphine (1·3 g, 5 mmol; previously dried *in vacuo* for 4 h at 60°). The mixture was heated to melt the triphenylphosphine, homogenised by rapid stirring, and kept under reduced pressure for 2 h at 90°. On cooling a pale yellow glass (colourless if distilled chloromethyl ether had been used) was obtained which was homogeneous on t.l.c. (R_F 0·7 in propan-2-ol–water–ethyl acetate, 7 : 2 : 1) and exhibited u.v. absorption. The glass was pulverised in anhydrous ether, filtered off, and washed with ether (*N.B.* complete evaporation of the solvent should be avoided because of the hygroscopic character of the powder); the yield was quantitative at this stage. Crystallisation was effected by dissolving the powder in the minimum quantity of boiling propan-2-ol and adding ether to incipient turbidity. Storage overnight at 5° gave the *salt* (9) (2·09 g, 73%), m.p. 129—132°, δ ($CDCl_3$) 1·23 (3H, s, CMe), 1·32 (3H, s, CMe), 1·40 (3H, s, CMe), 1·46 (3H, s, CMe), 3·88 (4H, 4-H, 5-H, 6-H_2), 4·34 (1H, d, 3-H), 5·19 (1H, d, $J_{1,2}$ 3·5 Hz, 2-H), 5·50 (1H, q, J_{PH_a} 6·0, $J_{H_aH_b}$ 13·5 Hz, $P{\cdot}CH_a{-}O$), 5·76 (1H, d, 1-H), 6·52 (1H, q, J_{PH_b} 4·5 Hz, $P{\cdot}CH_b{-}O$), 7·72 (15 H, PPh_3) (Found: P, 5·7. $C_{31}H_{36}ClO_6P$ requires P, 5·4%).

cis–trans-*Mixture of Dienyl Ethers* (5) *and* (6).—A solution of phenyl-lithium (13 mmol) in di-n-butyl ether was added to a suspension of the phosphonium salt (9) (3·7 g, 6·5 mmol; dried *in vacuo* at 40° for 12 h) in anhydrous ether through which was passed a stream of dry nitrogen. The liquid gradually became deep red and the phosphonium salt passed into solution. Acrylaldehyde (0·5 ml, 18 mmol) was added after 10 min and the solution was immediately decolourised, with formation of a white precipitate. The mixture was filtered after 5 min and t.l.c. (benzene–ethyl acetate, 6 : 1) indicated the presence of one major component (R_F 0·7; u.v.-absorbing) in the filtrate. Chromatography on silica gel (benzene–ethyl acetate, 6 : 1) gave a liquid (1·0 g, 50%), b.p. 110° at 0·02 mmHg, $\nu_{max.}$ (film) 1600 and 1650 cm^{-1} (diene); n.m.r. spectrum as for a mixture of (5) and (6) (Found: C, 61·3; H, 7·8; O, 30·5%).

Cycloaddition of Butyl Glyoxylate to the trans-*Dienyl Ether* (6).—A mixture of (6) (1·9 g, 6·1 mmol) and butyl glyoxylate (1 ml) was stored at ambient temperature for 15 days (or for 3 days at 60°). Chromatography on silica gel (78 × 4 cm) with ether–petroleum (1 : 1) then gave a mixture (2·49 g, 92·5%) of four isomers (10), (13), (11), and (12) in order of increasing polarity.

The same result was obtained by starting with a *cis–trans* mixture [(5) and (6)] obtained by partial hydrogenation of the mixture of enynyl ethers (3) and (4) or by the Wittig reaction; the yield was also the same (based on the amount of *trans*-diene in the mixture).

The product mixture was rechromatographed with ether–petroleum (1 : 1) as eluant to give a mixture of (10) and (13) (73%), b.p. 165° at 0·1 mmHg (Found: C, 59·4; H, 7·65; O, 32·65. Calc. for $C_{22}H_{34}O_9$: C, 59·7; H, 7·75; O, 32·55%). Continued elution gave (11) and (12) in the ratio 2 : 1 as nearly pure fractions.

Isomerisation in Acidic Media: O-(*Butyl* 2,3,4-*trideoxy*-α-D-*glycerohex*-2-*enopyranosyluronate*)-(1 ⟶ 3)-1,2:5,6-*di*-O-*isopropylidene*-α-D-*glucofuranose* (10).—The mixture (10)—(13) (1 g) was either (*a*) dissolved in benzene (10 ml) containing toluene-sulphonic acid (5 mg) or (*b*) dissolved in anhydrous ether (20 ml) containing boron trifluoride–ether complex (2 drops).

In each case, the mixture was stirred for 2 h at ambient temperature then washed with aqueous sodium hydrogen carbonate and water, dried, and concentrated. The residue was chromatographed on silica gel with ether–petroleum (1 : 1) to give initially compound (10) (25%), $[\alpha]_D^{20}$ −48·3° (*c* 0·77 in $CHCl_3$), $\nu_{max.}$ (film) 1370 and 1380 (CMe_2), 1650 (C=C), and 1740 cm^{-1} (CO).

Continued elution gave the α-L-*glycero*-isomer (12) (55%), $[\alpha]_D^{25}$ +11·6° (*c* 0·78 in $CHCl_3$), $\nu_{max.}$ (film) 1370 and 1380 (CMe_2), 1650 (C=C),, and 1750 cm^{-1} (CO).†

† For want of a suitable analytical method, we can only give an approximate estimate of the proportions of compounds (10)—(13) in the mixture resulting from the cycloaddition, but the subsequent separations nevertheless give certain indications. If the percentage of each component in the mixture is designated by [10], [11] . . ., then the results of column chromatography give [10] + [13] = 0·73 and [11]/[12] = 2. Denoting the isomerisations by [11] ⟶ [10], [13] ⟶ [12], and assuming that the extent of decomposition of each of the four compounds is the same, we can write ([10] + [11])/([12] + [13]) = 25/55, from which [10] = 13%, [11] = 18%, [12] = 9%, [13] = 60%. A predominance of the products of *cis*-configuration is thus observed.

Isomerisation in Basic Medium.—A solution of the mixture of (10) and (13) obtained above in butanol containing sodium butoxide (1%) was stored at room temperature; t.l.c. (chloroform–methanol, 99 : 1) after 3 h indicated a significant conversion of (13) into (10), without the formation of other isomers. Similar treatment of a mixture of (11) and (12) resulted in a partial conversion of (11) into (12), as shown by t.l.c. (ether–petroleum, 1 : 1). In neither case could complete conversion into a single component be achieved because of simultaneous decomposition which was complete within 36 h.

O-(2,3,4-*Trideoxy*-α-D-glycero-*hexopyranosyl*)-(1 ⟶ 3)-1,2:5,6-*di*-O-*isopropylidene*-α-D-*glucofuranose* (20).—A solution of (10) (534 mg) in ether (10 ml) was added dropwise to a stirred suspension of lithium aluminium hydride (210 mg) in ether (10 ml). After 2 h, ice–water was added and the ethereal layer was separated, dried, and concentrated to an oil. A solution of the residue, containing (19), in methanol (110 ml) was hydrogenated over Adams catalyst (freshly prepared by reduction of platinum oxide; 110 mg) for 2 h. Filtration through Celite and concentration of the filtrate gave the crystalline *product* (20) (390 mg, 87%), m.p. 112—115° (from methanol–ether) (Found: C, 58·1; H, 7·95; O, 34·0. $C_{18}H_{28}O_8$ requires C, 58·05; H, 7·6; O, 34·35%).

O-(2,3,4-*Trideoxy*-α-L-glycero-*hex*-2-*enopyranosyl*)-(1 ⟶ 3)-1,2:5,6-*di*-O-*isopropylidene*-α-D-*glucofuranose* (21).—A solution of (10) (913 mg) in ether (20 ml) was added dropwise to a suspension of lithium aluminium hydride (350 mg) in ether (20 ml) stirred at room temperature. After 2 h the mixture was worked up as above, to give compound (21) (680 mg, 89%), m.p. 148—149° (from ether), $\nu_{max.}$ (KBr) 1655 (C=C) and 3040 cm^{-1} (CH=) (Found: C, 58·4; H, 7·45; O, 34·3%).

O-(2,3,4-*Trideoxy*-α-L-glycero-*hexopyranosyl*)-(1 ⟶ 3)-1,2:5,6-*di*-O-*isopropylidene*-α-D-*glucofuranose* (22).—A solution of (21) (330) mg) in methanol was stirred with platinum oxide (100 mg) in hydrogen for 2 h. Work-up in the usual manner gave (22) (320 mg, 97%) as a syrup, homogeneous on t.l.c. (chloroform–methanol, 99 : 5).

(S)-4-(4,4-*Diethoxybutyl*)-2,2-*dimethyldioxolan* (15).—A mixture of triphenylphosphine (26·2 g, 0·1 mol) and 3-chloro-1,1-diethoxypropane (18·3 ml, 0·1 mol) was heated at 130° for 15 min under nitrogen and then allowed to cool to 50°. Tetrahydrofuran (200 ml) was added, followed by a solution of phenyl-lithium in benzene–ether (Fluka). After 3 h at 50°, 2,3-*O*-isopropylidene-D-glyceraldehyde (13 g) was added and the mixture was kept at room temperature for 16 h. It was concentrated to dryness and the residue was dissolved in water, while maintaining the solution at pH 6 by addition of dilute acetic acid. The aqueous solution was extracted with ether and the organic phase was concentrated. The residue was applied to a column of silica gel (1 kg). Elution with benzene–ethyl acetate (6 : 1) gave 4-(4,4-*diethoxybut*-1-*enyl*)-2,2-*dimethyldioxolan* (14) (3·5 g, 14%) as an oil, b.p. 90—95° at 0·01 mmHg (Found: C, 63·7; H, 9·9; O, 26·0. $C_{13}H_{24}O_4$ requires C, 63·9; H, 9·9; O, 26·2%).

A solution of compound (14) (480 mg) in ethanol (10 ml) was hydrogenated over 5% palladium–charcoal (60 mg) for 3 h. Work-up in the usual way gave the *dioxolan* (15) (472 mg, 97%) as an oil, b.p. 85° at 0·01 mmHg (Found: C, 63·3; H, 10·7; O, 26·1. $C_{13}H_{26}O_4$ requires C, 63·4; H, 10·65; O, 26·0%).

2,3,4-*Trideoxy*-D-*hexopyranose* (17).—A solution of (15) (882 mg) in 0·5M-sulphuric acid (20 ml) was heated at 100° for 1 h, cooled, neutralised ($BaCO_3$), filtered, and concentrated to dryness. Elution of the residue from a column of silica gel (45 × 2 cm) with chloroform–methanol (9 : 1) gave the *product* (17 (57 mg, 12%) as an oil, homogeneous on t.l.c., b.p. 105° at 0·01 mmHg, $[\alpha]_D^{25}$ +46·9° (*c* 4·7 in CH_2Cl_2) (Found: C, 54·3; H, 9·2; O, 36·55. $C_6H_{12}O_3$ requires C, 54·5; H, 9·15; O, 36·3%).

Hydrolysis of (15) with 80% acetic acid (100°; 1 h) led to the ethyl glycoside (16) (Found: C, 60·55; H, 9·8; O, 30·05. $C_8H_{16}O_3$ requires C, 60·0; H, 10·1; O, 29·95%), which on treatment with dilute sulphuric acid as above gave (17).

Hydrolysis of the Trideoxydisaccharide (20).—A solution of compound (20) (313 mg) in 0·5M-sulphuric acid (5 ml) was heated at 100° for 1 h. Neutralisation ($BaCO_3$), filtration, and concentration of the filtrate gave a residue which was redissolved in chloroform–methanol (9 : 1) and chromatographed on silica gel (elution with the same solvent). Compound (17) (29 mg, 26%), $[\alpha]_D^{25}$ +45·9° (*c* 1·4 in CH_2Cl_2) was obtained as an oil, homogeneous on t.l.c.

2,3,4-*Trideoxy*-L-*hexopyranose* (18).—Compound (22) was treated by the method described above to give (18) (21 mg, 18%), $[\alpha]_D^{25}$ −44·2° (*c* 1·8 in CH_2Cl_2), which exhibited chromatographic properties identical with those of (17).

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